§21. Development of Dynamic Simulator for Large Superconducting Magnet System

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The superconducting magnets for the SiD and ILD detectors are essential components of the International Linear Collider (ILC) experiment. As shown in the Fig.1 the central region can be regarded as interface between detector and accelerator i.e. final focusing magnets, which are referred to as QD0 and QF1, are installed inside and adjacent to the detectors. Cryostats for crab cavity (CC) are also installed adjacent to QF1 magnets. Both detectors (SiD, ILD) are cooled by gas-liquid two phase flow of helium with the temperature of 4.5 K. The final focusing magnets (QD0, QF1) and crab cavity (CC) have to be cooled by pressurized and saturated superfluid helium, respectively. Therefore from the viewpoint of cryogenics, we have to consider the cryogenic system not only for detectors but also for accelerator such as QD0, QF1 and crab cavity to configure more sophisticated cryogenic flow scheme in the central region. In the central region, there are two notable points. First one is push-pull operation of the detectors i.e. two detectors move from collision point to maintenance location up to twice a month. The moving distance for push-pull operation is 28 m in the case of Japanese mountain site. The cryogenic system has to employ some kind of flexible type tube for warm or cold helium. Whether warm or cold flexible tube has to be employed strongly depends on cryogenic flow diagram of the central region. Second one is that acceptable vibration level for final focusing magnet, QD0, is very small. Actually, the maximum allowable vibration level is around 50 nm. To reduce vibration generated in the QD0, we have to pay special attention to various kinds of vibration source due to the mechanical vibration and fluid motion etc.

In this study, following 3 kinds of simulation tools have been developed to establish optimal design of the cryogenics for the central region of ILC.

1. Two phase flow simulations with respect to the forced cooling and thermosyphon cooling for the large superconducting solenoid.
2. Superfluid simulation for the cooling of final focusing magnets.
3. Dynamic Simulation on 2K-4K combined cryogenic system in order to find optimal cryogenic flow diagram for central region.

In the FY2013, we developed the numerical simulation code for two phase flow in horizontal and vertical channels and parallel channel system. Parallel cooling channel systems are often employed in the large superconducting magnet system. But in this case we have to pay attention to the two phase flow instability generated in the parallel cooling channel. Fig.2 (A) shows flow pattern in the horizontal and vertical channels obtained from simulations. Fig.2 (B) indicates time dependent of liquid fraction generated in the 4 parallel cooling channels. As shown in the Fig.2 (B), if the inlet quality is less than 0.1, flow instability does not occur in the outlet channels. On the contrary, in the case that the inlet quality is 0.3, flow instability occurs in a outlet 1. In this case, cooling efficiency in the outlet1 decreases in comparison with other cooling channels due to the existence of mass flow inhomogeneity in the outlet1.

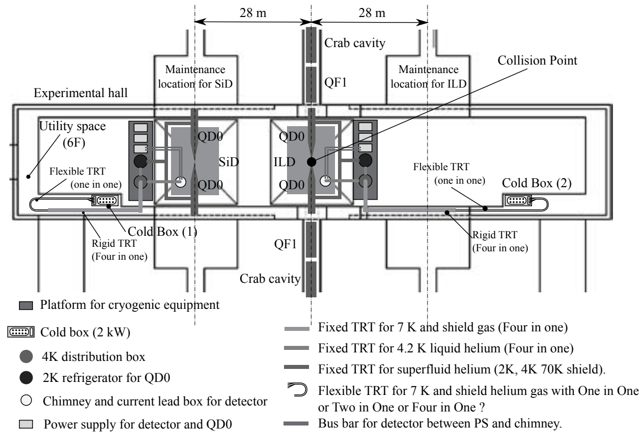

Fig. 1: Schematic view of cryogenic system in the central region for ILC.

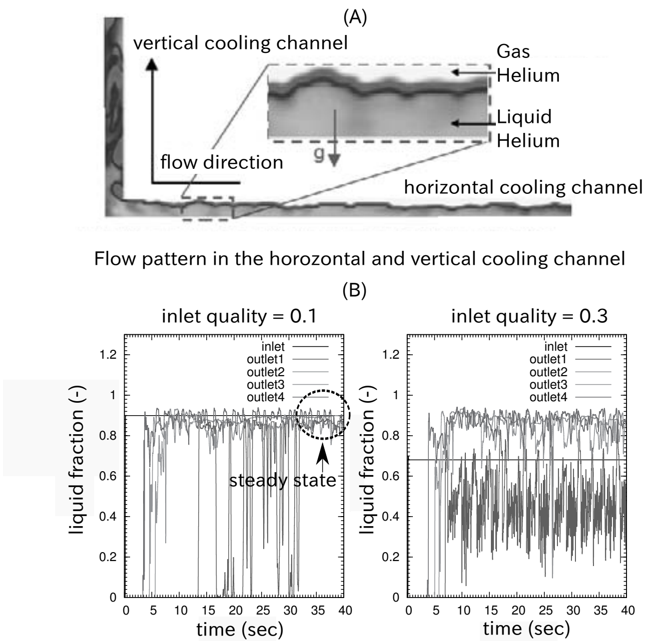

Fig. 2: (A) Flow pattern in the horizontal and vertical channel. (B) Flow instability generated in the 4 parallel channels.